HUMIDITY

IN

COTTON SPINNING.

A PAPER BY

B. A. DOBSON, C.E., M.I.M.E.,

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J. D. Aiken –

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B. A. DOBSON, C.E., M.I.M.E.,

CHEVALIER DE LA LEGION D'HONNEUR.

(AUTHOR OF "THE PRINCIPLES OF CARDING COTTON,"
"SOME DIFFICULTIES IN COTTON SPINNING," &c., &c.)

READ AT THE

BOLTON TECHNICAL SCHOOL,

BEFORE THE TECHNICAL INSTRUCTION COMMITTEES, MASTER COTTON SPINNERS, MILL MANAGERS TECHNICAL ASSOCIATION, AND MANAGERS AND OVERLOOKERS ASSOCIATION OF BOLTON AND DISTRICT, AND COMMUNICATED TO THE NEW ENGLAND COTTON MANUFACTURERS ASSOCIATION, BOSTON, U.S.A.

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PREFACE.

What I intended originally to be a few Notes on the subject of Humidity in Cotton Spinning has, by force of circumstances, expanded into a fairly sized booklet. Again, whereas, at first, no illustrations were contemplated, I have found it necessary, for the purpose of explanation, to include several. I trust the result may be of practical benefit to the trade concerned, if not directly by the information I have given, at least indirectly by the criticism it may induce.

B. A. DOBSON.

Bolton,

December, 1894.

HUMIDITY IN COTTON SPINNING.

THE general interest taken in this subject, judging by the number of papers lately read and the discussions upon them, only points to the fact that it is a subject, the scientific study of which has been somewhat neglected.

We in this part of England, in Lancashire, have too long considered that we are specially favoured by nature in some very great degree, and that outside this county fine cotton spinning has been next to an impossibility. This raises the question of climatic suitability; and I propose to consider, shortly, from a practical point of view, those conditions which concern the subject, and the means of modifying unfavourable circumstances, in order to produce better results in the processes of manufacture.

Some two years ago, I caused to be made an elaborate system of observations in mills spinning different numbers, with a view of ascertaining what degree of comparative similarity in atmospheric conditions could be found in mills spinning much the same numbers for the same market, in trade competition. I discovered, to my surprise, that this important question was very much neglected from, as I have just said, a scientific point of view. There are many mills where there are no instruments for ascertaining, exactly, the climatic conditions—in some other establishments, however, the use of them forms part of the duty of the staff and of the

daily routine. I found, further, that where science had not been consulted the natural resource of the work-people exhibited itself in the most practical and simple way. Thus, in weather when a dry east wind and low temperature produced an atmosphere unfavourable for spinning, that friend of the cotton spinner, the "degging can," came into legitimate and successful operation.

The climate most resembling that of Lancashire is the flat plain of Lower Flanders, known now as the Departement du Nord, in which is situated the wealthy, important, and thriving town of Lille.

The cotton spinning industry in this district is almost as old as that of this country. And I may say, as regards fine spinning, it has been carried as far towards perfection as it is here; and that so far as results are concerned, the people have little to learn from us. On the other hand, the fact of the mills being comparatively small, with a limited number of spindles to each establishment, causes an uneconomical result in cost of production which, in spite of duties, permits of competition from our own country.

OLD COTTON MILLS IN LILLE.

It may be said, broadly, that the mills constructed some seventy or more years ago were built exactly on the same plan as the mills erected in the city of Manchester and district at the same date, or previously, allowing for the peculiarity of construction obtaining in the two countries.

Thus the buildings had thick walls and small windows, and the ceilings were lower. The entrance to each spinning room was from the staircase, well protected below from sudden incursions of cold winds; and the

floors, and woodwork generally, were saturated with many years' accumulation of oil. This circumstance alone is of importance, inasmuch as the oil would form a sort of protection against sudden changes of temperature of the floor or walls or ceilings. Again, the small size of the rooms, and the little opportunity for the entrance of extraneous air, made the problem of maintaining an equable temperature one easier to solve.

It is within my knowledge that a firm in this county of Lancashire, having a very ancient building constructed according to the foregoing particulars, and having a modern mill with increased floor space, window space, and height of ceiling, have found it impossible to spin the same numbers with equal results, the yarn from the old mill invariably being smoother. This will form the text upon which I am proceeding.

RELATION OF HEAT TO FIBRE.

It may be well to state at this point—although I presume most persons in the business of cotton spinning know it as well or better than I do myself—the reasons why cotton will spin better at one time than another. There are two causes for this, one of which hinges upon the peculiarity of the structure of the cotton fibre. If the cotton fibre be cold and dry it is what is termed "harsh;" and a spinner who is accustomed to pull cotton can instinctively make allowance for the degree of dryness of that cotton he is testing. When the fibre is cold and dry the waxy envelope of the fibre is congealed; and, consequently, there is some resistance of the fibre to the processes of manufacturing, known as "drawing" and "spinning." Although I have stated this very simply, I believe I have named all the facts as regards the relation of heat, *per se*, in its effect upon the fibre.

Now if this were all, it would be enough if heated air were supplied in sufficient temperature to maintain the fibre in a supple condition. But here comes in another factor in the problem. If the fibre be hot and dry it is peculiarly susceptible to the influence of electricity. This is a phenomenon often most difficult to deal with.

EFFECTS OF ELECTRICITY.

From first to last, in a cotton spinning mill, free electricity interferes in each operation with the process of manufacture. Opener, scutcher, card, drawframe, flyframe, and mule or throstle—if the conditions are such that electricity has perfect liberty, the result must show inferiority of the product. I have seen mills of recent construction, especially fireproof mills, where every shaft, column, and beam in the fabric of the mill were charged with electricity to such a degree that cotton fibre stood out from the ironwork to the distance of at least three inches—radially to the centre of electric attraction. An infallible and ready proof of the existence of the electricity is in carefully observing the ironwork of the machines. Of course, in all mills, there is a certain amount of loose fibre called "fly" floating in the air. If it is found on any of the ironwork standing straight up from the surface like the bristles of a brush, there is no necessity for further argument—the presence of electricity is declared. Very often this comes from the slipping friction of the driving straps and is conveyed, say, from the driving shaft pulley to the pulley of the machine; charging the body of metal with latent electricity, which, in its turn, affects every fibre in its passage.

I have tried, occasionally, to extract the electricity from the machine, with very considerable success. Thus

with a copper wire attached to any part of ironwork forming what is termed "earth," by placing the other end of the wire near the inside of the leading strap, the electricity was taken from the strap and prevented from going into the machine itself. On a revolving flat carding engine, which was so charged by electricity that the fly on the flats stood straight up from the wires. I have been able, by the movement of the wire, to make this fibre rise and fall at will. In combing machines, where it is desired to comb as much width of lap as may be practicable for the length of the roller, this action of electricity is very marked, and becomes of great importance.

A very large and eminent spinning firm in America had a number of combers made to comb the same width of lap as they had seen successfully combed in a mill in this country; but after a year's trial they found so much difficulty and so much waste made that they went to the extreme course of sending their manager to England to see, again, the machines which had served as a sample for the giving of the order; to ascertain whether they did work as satisfactorily as the firm had supposed. They found that the machines did so; and the firm were forced to the conclusion that they would have to comb a lap one inch narrower than we can do in Lancashire, on account of the effect of the latent electricity upon the loose fibres of cotton.

The action is to separate the fibres. Fibres under this influence cannot be brought together; consequently, more room is required for the operation. I have, myself, seen not once, but several times, the cotton issuing from a drawframe roller refuse to pass down the funnel to the coiler, and float in the air like a snake right over the calender rollers on to the floor.

What is true of the card, comber, and drawframe, is also true of the flyframes and spinning machines. But in the spinning machines the presence of electricity is shown by accumulation of fly on the working parts—the rough, furry, character of the thread made, and its brittleness and liability to snap. As showing the extraordinary effects that can be produced by this, I know of a mill which, when starting its new machinery, had several breakdowns of the openers and scutchers; but, more particularly scutchers, after stopping the machine and restarting. A little observation showed that in each case a huge parcel of cotton of considerable density had been carried to the metallic cages, and, by over pressure, owing to the great thickness, had caused breakages of the wheels. A little examination showed that, after running some time, the whole of the interior of the beaters, from the centre shaft to the blade of the beater, contained a dense block of cotton, which filled in the space as symetrically as if it had been made purposely in wood. After a certain time, when the machine had been stopped long enough to allow the electricity to be disengaged, these pieces fell as the machine restarted and were thrown by centrifugal force into the cages.

I examined these extraordinary blocks of cotton and found that the fibres were ranged parallel end to end in line from the centre of the beater shaft to the inside surface of the beater blade. In this case, the objectionable phenomenon disappeared as soon as the room had been heated, and the straps driving the machine had been thoroughly well moistened with composition. The fact was the machines were at first thoroughly insulated from the floor; the driving strap slipping on the line shaft pulley was acting as a sort of electric machine and

charging, by means of the strap, the opening or scutching machine driven.

In America, this has been considered of such importance that in many mills there are special arrangements for preventing conduction of electricity from the driving straps to the machines.

Mr. Buchanan says in the Phil. Mag., U.S., Vol. I., page 581, that in a "factory at Glasgow the accumulation of electricity in one room in particular, in which was a large cast iron lathe, shears, and other machinery driven with great velocity by belts was so great that it was necessary, in order to protect the workmen from unpleasant shocks, to connect the machinery with copper wire with the iron columns of the buildings, and that when a break in the wire was made at a quarter of an inch the succession of sparks was very rapid. The electricity was positive."

Thus in the case of the scutchers I have named the phenomenon ceased when the slipping of the strap was prevented by the composition which, at the same time, acted as a non-conductor, preventing the surface of the leather from touching the surface of the iron drum.

In connection with this subject of electricity and its practical effect upon spinning, I would refer to a pamphlet by Mr. Harry S. Chase, read at the Massachusetts Institute of Technology, in 1883, in which the phenomenon occasioned by electricity in spinning white cotton, dyed cotton, and natural and dyed wools, is very fully dealt with; and in which the author describes different methods by which electricity can be generated in a spinning mill and communicated to the material under operation; as, also, the best method of preventing or removing the electricity. It would seem from the result

of Mr. Chase's investigations that the principal cause is the friction occasioned by the slip and pressure of the strap on the driving pulley, in which, as in all electrical phenomena, the surface of the strap will produce one electricity and the pulley another. In every case tested, the electricity developed was negative in the belt and positive in the pulley. Above and beyond the difficulty occasioned by this occurrence, there is a greater one in that the stock of material may be charged with electricity generated elsewhere, and communicated by beams, pillars, gas pipes, or bolts. Cases have been known where the cotton in the mixing room was severely charged from the bolt heads of the hangers driving the machinery pulley. It may be said, *en passant*, that material, either cotton or wool, charged with electricity is exceedingly difficult to discharge; and only time and a kindly atmosphere can effectually perform this. The author also mentions the effect of steam being allowed to flow into rooms, principally weaving sheds, for humidifying purposes, in order that "electricity may be killed;" and where it was found that the very opposite effect was produced, from the fact that steam was developing the same quality of electricity as that existing in the room. The writer completes his paper by discussing the question of moisture in the air and the extent of steam admitted, further pointing out that a too great proportion of moisture would have an injurious effect upon the work, as the springs and elasticity of the fibre is weakened. He then makes some general remarks upon the observations of the hygrometer, and draws a conclusion with which I must strongly disagree; one in which he states that the humidity for good working is less than expected, and he places the limitation between bad and good work at from 30 to 40 per cent. of saturation. This I think will, further on, be

seen to be quite outside the mark; and Mr. Chase winds up with an assertion I reproduce literally: "A careful consideration of these statements will satisfactorily prove, I think, that the whole question of escaping from electrical trouble will be found in the matter of relative humidity. If there is sufficient moisture in the atmosphere, there is no trouble; if there is not sufficient moisture, electricity always appears. The question is resolved into deciding on the best and most satisfactory method of getting the moisture into the mills and this brings in, as all improvements ultimately do, the consideration of the relative cost of the annoyances and the cure."

HYGROMETRICAL CONDITIONS OF THE ATMOSPHERE.

Now the author might have gone even further than he has done, and pointed out the impossibility of producing good yarns in either cotton or wool, if the hygrometrical conditions of the atmosphere were unfavourable; the reason being, as I have stated before, that the effect of the existence of the free or latent electricity is to produce mutual repulsion in the fibres being dealt with; and therefore in the processes of spinning and twisting the end of the fibre not immediately under control has a tendency to radiate from the centre of the body of fibres in action, and to produce rough, or what is familiarly known as "oozy" yarn. I may say that the only effective method of avoiding the inconveniences previously alluded to is by moistening the air to such an extent that it will prove a sufficiently good conductor to disengage the electricity existing in the fibres.

In countries where there is a very wide range of temperature and where the climate at certain seasons is

excessively dry, these differences are more serious than in countries where the contrary obtains; although even in this climate of Lancashire the difference between a west wind and an east wind often makes a margin of 7 to 8½ per cent. in the production of a weaving shed.

Boston is the chief town of Massachusetts and is, to a certain extent, a centre of manufacturing, and may almost be termed the American Manchester. The mills are not immediately in the town. They are at short distances round and are in practically much the same climate as the town of Boston itself. What difference there is, is perhaps rather against the manufacturing districts, as most of them are inland from Boston, and, consequently, there is slightly less humidity than in the neighbourhood of the coast line, where the vicinity of the ocean tends to make the climate equable.

COMPARISONS OF DISTRICTS.

In making a comparison between one district and another, as regards its capabilities for manufacture there are several points which must be carefully weighed in all cases; the first being the question of mean temperature, the second the extreme range of temperature, and the third the natural percentage of humidity under the varying temperatures. I append a table of statistics with regard to the foregoing conditions and will endeavour to deduce the values, for the purpose of manufacturing—say cotton spinning, in each case. I have taken twelve parts of the world—the 10th, 11th and 12th being, respectively, Boston (Mass.), Bolton, Lancashire, and the district near Lille. I will proceed to show why, and to what degree, each is favoured by its climatic peculiarities for this particular industry. I have given in each case

the maximum and minimum temperature and the mean maximum and minimum of humidity, and, also, the calculated annual mean. The latter is of little value as a factor in the problem, as, of course, extremes of conditions of humidity would not affect the calculated mean; although one extreme, or the other, or both, might be very prejudicial to the working of the fibre. And I may state, as a principle, that the less the range of temperature, and the more regular the degree of humidity, the better the conditions. Thus, for instance, take the contrast between Boston and Bolton. I find the highest monthly mean humidity in Boston to be 85 per cent., against Bolton 93·1 per cent.; the lowest monthly mean 66 per cent., against our 69 per cent. Moreover, comparing the annual mean humidity, Boston 74·5 per cent., and Bolton 81·9 per cent., the contrast shows an immense advantage for cotton spinning here. Again, take the range of temperature—in Bolton it is 62·8 deg., whilst in Boston it is 92 deg.

When the temperature in Boston is minus 1 degree, the amount of vapour in suspension would be practically nil, or about half a grain per cubic foot; consequently, when the air is heated sufficiently to allow of spinning operations, it would be absolutely necessary, even for considerations of health alone, to impart an artificial humidity. The conditions of the district near Lille will be seen; they resemble closely those of Bolton.

On the following page will be found the tabulated statement referred to, with criticisms on the adaptability of the various climates for spinning.

	TEMPERATURE.					HUMIDITY.							
	Annual Mean.	Month Max.	No. of Month.	Month Min.	No. of Month.	Annual Mean.	Highest Monthly Mean.	No. of Month.	Lowest Monthly Mean.	No. of Month.	Annual Max. at 10 a.m. & 4 p.m.	Annual Rainfall.	REMARKS.
						%	%		%		%	ins.	
1.—Bombay, India	79·5°	84·7°	5	73·1°	1	75	86	4,5	64	12	73-70	74·23	Its disadvantages are, the low percentage of humidity and its wide range.
2.—Madras, ,, ...	81·8	87·2	4, 5	75·5	1	78	84	5	72	1	77-61	49·34	Very similar to Bombay with rather wider range.
3.—Adelaide, Australia	63	112	1	34·7	7	59	84	8	30	2	..	20·44	Both temperature and humidity have too great a range (the latter having also great diurnal variation) for cotton spinning.
4.—Madagascar............	73·4	94	1	50	7	81	83	5,9	80	3	..	145·34	Climatic conditions seem favourable for cotton spinning.
5.—Ichang, China..........	63·5	107·2	7, 11	22	2, 12	78	82	4,12	78	6	..	44·60	The max. temperature would be too high for successful spinning.
6.—Chicago, Illinois, U.S.A.	48·8	90	7	—11	2	75	86	11	63	8	a.m. p.m. 78-72	34·95	Unsuitable on account of its extreme annual range of temperature, the low mean and wide range of humidity, as well as the daily variability which occurs between 10 a.m. and 4 p.m.
7.—New Orleans, Louisa. ,,	68·8	95	7	32	2	78·5	91	12	58	5	84-73	48·45	Both the daily and annual range of humidity is much in excess of more favoured localities.
8.—New York City, ,,	53·5	90	8	2	2	75·5	82	9	68	3,4	77-74	58·68	The range in temperature is too great, as well as the variability of its humidity.
9.—Salt Lake, Utah. ,,	52·7	102	7	5	1	49·5	76	2	17	7	56-43	18·46	Probably the most unfavourable of all parts of the earth for cotton spinning.
10.—Boston, Mass. ,,	50·7	91	5	—1	2	74·5	85	9	66	12	75-74	39·82	See remarks pages 10 and 11.
11.—Bolton, Lancashire	46·33	55·08	8	31·99	12	81·9	93·1	2	69	5	82-82	42·245	,, ,, ,,
12.—Lille, France	48.8	71·4	7	23·3	1	84·2	93	12	78	5	..	26·31	Humidity highly favourable, but the range of annual temperature much wider than Bolton.

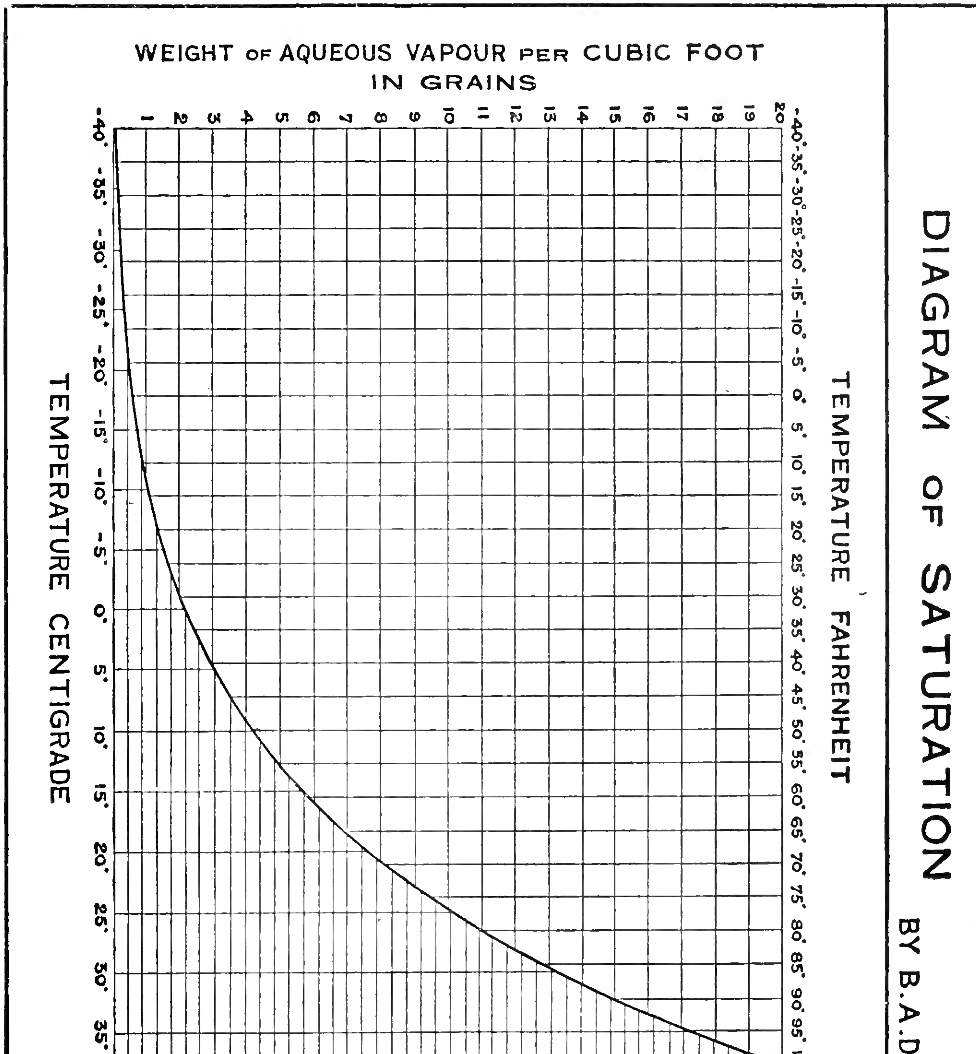


DIAGRAM OF SATURATION
BY B.A. DOBSON
WEIGHT OF AQUEOUS VAPOUR PER CUBIC FOOT IN GRAINS
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
POIDS DE VAPEUR PAR METRE CUBE EN GRAMMES
5 10 15 20 25 30 35 40 45
TEMPERATURE CENTIGRADE
-40° -35° -30° -25° -20° -15° -10° -5° 0° 5° 10° 15° 20° 25° 30° 35°
TEMPERATURE FAHRENHEIT
-40° -35° -30° -25° -20° -15° -10° -5° 0° 5° 10° 15° 20° 25° 30° 35° 40° 45° 50° 55° 60° 65° 70° 75° 80° 85° 90° 95° 100°

INFLUENCE OF VAPOUR.

That those who have not had an opportunity of studying the question of the principles involved in evaporation and in suspended vapour may do so, I append a table diagram on page 13 from which may be seen, at a glance, the weight of vapour per cubic foot, or per cubic metre, which constitutes what is known as saturation; saturation, of course, meaning that each particle of air is supporting as much weight of fluid in its minute globular form as it is capable of doing. This is known as the elastic force of aqueous vapour. The table is read from the perpendicular column on the left to find the number of grains per cubic foot, and along the upper column to find the temperature on the Fahrenheit scale. On the right hand are the number of gramms per cubic metre, and on the bottom the scale of temperature on the centigrade scale. Thus, by reading up from the bottom and from the left, the weight of aqueous vapour required to saturate a cubic foot at any temperature in the scale can be readily seen, and the same by reading from the right hand side and from the bottom for the metric system. It will be seen that, as the temperature rises, the air is capable of containing more and more moisture. Thus, at 212 degrees Fahr., the air would be developing steam, and that at 40 degrees below zero, Fahr., the air is not capable of supporting vapour.

This, of course, accounts for the bright crisp air in excessively cold weather, and for the muggy damp air occasionally met with in the dog days. It accounts, likewise, for the phenomenon met with in the cold countries, such as Canada or Russia, where, on a bright sunlight day, with a blue sky, finely powdered snow falls in quantity; the fact being that a stratum of air which, by

its greater temperature has absorbed moisture, elsewhere, is suddenly congealed and obliged to part with that portion of vapour over and above its proper quantity for its temperature. Further, it is responsible for the heavy dew in hot weather, where, when the air has been heated all day, and the moisture of the earth and the surface of adjacent water has been evaporated by the heat of the sun, and taken into suspension by the heated air, at sundown, the difference of temperature, owing to terrestrial radiation, forces the air to part with its excess of moisture. Thus, as I have practically proved, it is possible in the tropics, to become wet through in a two miles' walk after 9 o'clock in the evening, the moisture formed on the clothing being visible and perceptible to touch.

In the proceedings of the Royal Meteorological Society of January, 1893, under the heading of "Correspondence and Notes," there is a statement referred to by Mr. F. E. Saunders in the "Bulletin of the New England Weather Service for September, 1892," in which he states:—

"It is a well-known fact that the temperature has quite an important bearing upon cotton fibres during the manipulation from the bale to the cloth-room. This must be evident to the most casual observer when we consider the fact that cotton is grown in a warm climate, surrounded by a mean temperature of 70 deg. and then transmitted to a climate that is subject to sudden atmospheric changes, many of them being of low temperature and with an atmosphere divested of moisture.

"Cotton fibres are very susceptible to any atmospheric change; that is to say, they will take on or throw

off dampness very readily, consequently any material change of temperature and humidity will affect the successful working of the fibre. In order for cotton to work well in the first processes of manipulation, the dry bulb thermometer of the common psychrometer should stand at 78 deg., and the wet bulb at 66 deg., which would make the dew point 58 deg., and the relative humidity 52 per cent. This would give 5·371 grains of water vapour per cubic foot of air. Cotton fibres, with this condition of atmosphere, will very readily assimilate and draw even. During very many of the atmospheric changes that are constantly taking place it is found quite impossible to hold the cotton fibres well in hand. This is more noticeable when dry atmosphere prevails with a dry west-north-west wind blowing for twenty-four or thirty-six hours. It is frequently the case, where these changes take place, that the amount of water vapour in a cubic foot of air will drop as low as 4·29 grains. When these conditions occur the electrical currents of air seriously interfere with the workings of cotton fibres. Electricity causes the fibres to separate, and much more waste is made. Very many of the cotton mills in New England are not supplied with moistening apparatus.*"

HUMIDITY AND TEMPERATURE.

It will be seen from the foregoing, that the question of humidity is intimately allied with that of temperature; and in manufactories it is first necessary to fix the temperature at which the workroom shall be kept and then to make such arrangements that this air may be supplied with the amount of moisture sufficient to make the air soft enough for the comfort of the workpeople and

* The use of hygrometers to indicate the condition of atmosphere in spinning mills was rendered compulsory in England by the Cotton Cloth Factories Act, 1889.

the conditioning of the fibre, and to render the atmosphere a sufficiently good conductor to subtract the extraneous and superfluous electricity. The following table gives the maximum amount of humidity allowed by the Act of Parliament referred to. It will be noticed that the vapour allowed is considerably in excess of any of the undermentioned observations:—

COTTON CLOTH FACTORIES ACT, 1889.

MAXIMUM LIMITS OF HUMIDITY OF THE ATMOSPHERE AT GIVEN TEMPERATURES.

Dry Bulb Readings.	Wet Bulb Readings.	Grains of Moisture per cubic foot of Air.	Percentage of Humidity Saturation = 100.	Dry Bulb Readings.	Wet Bulb Readings.	Grains of Moisture per cubic foot of Air.	Percentage of Humidity Saturation = 100.
35°	33°	1·9	80	68°	66°	6·6	88
36	34	2 0	82	69	67	6·9	88
37	35	2·1	83	70	68	7·1	88
38	36	2·2	83	71	68·5	7·1	85·5
39	37	2·3	84	72	69	7·1	84
40	38	2·4	84	73	70	7·4	84
41	39	2·5	84	74	70·5	7·4	81·5
42	40	2·6	85	75	71·5	7·65	81·5
43	41	2·7	84	76	72	7·7	79
44	42	2·8	84	77	73	8·0	79
45	43	2·9	85	78	73·5	8·0	77
46	44	3·1	86	79	74·5	8·25	77·5
47	45	3·2	86	80	75·5	8·55	77·5
48	46	3·3	86	81	76	8·6	76
49	47	3·4	86	82	76·5	8·65	74
50	48	3·5	86	83	77·5	8·85	74
51	49	3·6	86	84	78	8·9	72
52	50	3·8	86	85	79	9·2	72
53	51	3·9	86	86	80	9·5	72
54	52	4·1	86	87	80·5	9·55	71
55	53	4·2	87	88	81·5	9·9	71
56	54	4·4	87	89	82·5	10·25	71
57	55	4·5	87	90	83	10·3	69
58	56	4·7	87	91	83·5	10·35	68
59	57	4·9	88	92	84·5	10·7	68
60	58	5·1	88	93	85·5	11·0	68
61	59	5·2	88	94	86	11·1	66
62	60	5·4	88	95	87	11·5	66
63	61	5·6	88	96	88	11·8	66
64	62	5·8	88	97	88·5	11·9	65·5
65	63	6·0	88	98	89	12·0	64
66	64	6·2	88	99	90	12·3	64
67	65	6·4	88	100	91	12·7	64

It would be well to here show what inquiries and investigations I have made with a view of ascertaining

the exact working conditions obtaining in the district of Bolton, where our climate is supposed to be specially favourable for the spinning of super-extra quality of yarn. And I may say, in passing, it is a fact that no district has spun, so far, the special numbers and qualities of Bolton yarns to as good, or certainly not to better, advantage than is done here.

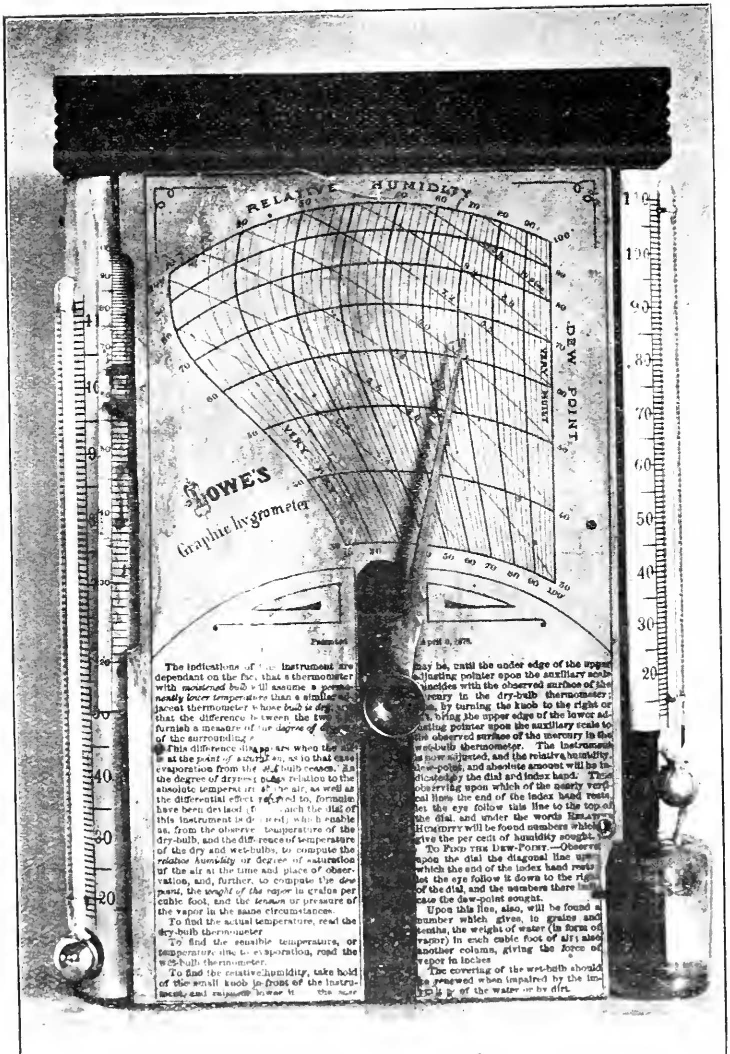
Knowing, as I did, personally, the conditions existing in a large number of manufactories, I could tell where and how to find the information that specially interested me. Therefore it was a more simple matter than would at first appear to find the typical examples and make the necessary comparisons. My examples have covered fifteen different mills, of which two were engaged in spinning wool. The numbers spun in these mills ranged from 40's to 160's. The mill spinning 160's had been arranged for much finer numbers, but, owing to the vagaries of the market, had spun considerably coarser numbers. Most of the mills were mule spinning; but one was a ring spinning mill, and one of the woollen mills was cap frame and the other mule spinning. I am glad to render tribute to the alacrity with which my request for permission to make these investigations was accorded in all cases. The only stipulation was that I would keep to myself the names of the firms concerned. This, I need hardly say, I have strictly complied with.

ADVANTAGES OF HYGROMETERS.

As will be seen from the foot-note to Mr. Saunders' remarks, the use of hygrometrical thermometers under the Cotton Cloth Factories Act, 1889, is compulsory. But the provisions do not extend to spinning mills. It is a great misfortune that it should not be wholly compulsory, because it would result in a better understanding of the

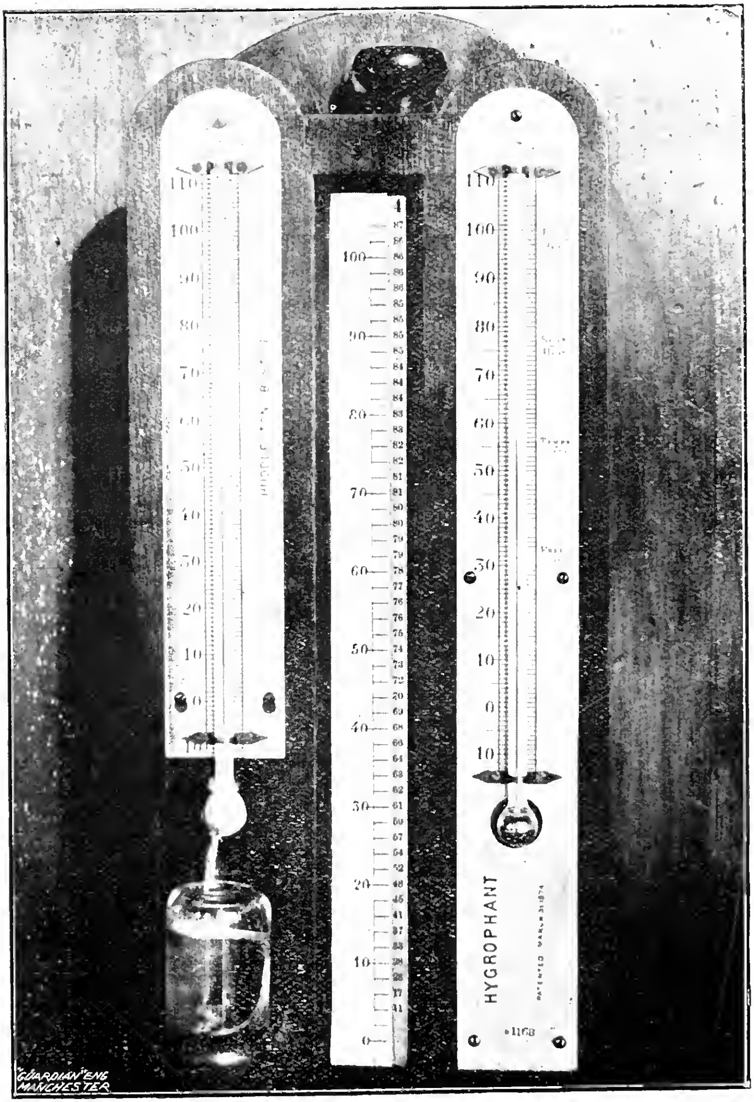
most favourable conditions for manufacture. In every case where I have examined the instruments I found the same radical defect. That is to say, the wet bulb and its well are so near the dry bulb as to affect the truth of the reductions of observation from 8 to 13 per cent. in the amounts calculated as percentage of humidity. Thus, in most cases, the thermometers were only $2\frac{1}{3}$ inches apart, and one I noticed in particular only $1\frac{1}{2}$ inches. Now the thermometers should not be less than 4 inches apart, and the well of the wet bulb should be at least 5 inches from the dry bulb. Even then, if observations are carefully noted, it will be found there is a difference of from 1 to $1\frac{1}{2}$ per cent. in apparent humidity between an observation in which the dry bulb is frequently wiped with a dry cloth and that in which it is left to acquire the moisture from the wet bulb, even at the distance of 4 inches. Thus in twenty-one readings under average circumstances, after allowing for corrections for what are known as "certified index errors," the standard instrument showed 83·1 deg., as against the mill instrument 77·7, and the standard instrument 95·2 against the other 89 deg. By carefully working out the figures, say of the first observation, it will prove, after the proper correction, a relative humidity to saturation, of 37 per cent. by the standard instrument and 55 per cent by the mill instrument. This will show how the mill people are deceived when they imagine that they are approaching the limit of humidity allowed by Act of Parliament, whereas, as a matter of fact, they are scarcely within measurable distance.

Those who have had to make the calculations to arrive at the percentage of humidity when worked out by what are known as Glaisher's Tables, will know there is a considerable amount of calculation, and if the observa-


RELATIVE HUMIDITY
DEW POINT
LOWE'S
Graphic hygrometer

tions are repeated and numerous, it is no small work to do this correctly.

Now as the principle involved in the differential value of the readings of the two thermometers follows an exact mathematical rule, it must be obvious there can be a mechanical method of reading the result without the calculations by means of curves or diagramatic interpretation. This principle has been most ingeniously worked out by an instrument-maker named Lowe in the town of Bridgeport, Connecticut, U.S.,A. With this instrument it is only necessary to read the temperature of the dry bulb (64°), then place the lower edge of the upper steel finger, seen to the left of the instrument, opposite the same temperature on the graded scale. This is done by sliding the milled head up or down as required. Then read the temperature of the wet bulb (58·7°), and turn the same milled head until the upper edge of the lower steel finger is level with that temperature. In doing this you move levers which bring the point of the indicator to that part of the chart where the relative humidity (72°/₀) can be read off—each of the thick vertical curves representing 10°/₀, and the intermediate ones 2°/₀. Other curves give the temperature of dew-point, and the weight of vapour per cubic foot of air. Upon testing, by exposing it alongside the two standard hygrometers, I found it took the large spherical bulbs of the thermometers four times as long to adapt themselves to the temperature of the mill as the long oval-shaped bulbs made by Casella of London; and the scale, being graded on the brass mountings instead of the stems of thermometers, gave reductions showing 7°/₀ more humidity than existed. This difference may arise either from the thermometers having slipped in the mount, or incorrectness of scale.


HYGROPHANT
"GUARDIAN" ENG
MANCHESTER

Another very ingenious instrument, "The Hygrophant," is one made by Huddleston of Boston, U.S.,A. This is even easier to understand than the preceding one, but confines itself to the finding of percentage of humidity. Indeed it is so simple that it might be called "Hygrometry made easy." First ascertain the number of degrees of difference between the temperatures of the wet and dry bulbs, then turn the vertical revolving drum placed between the thermometers until the figure in larger type at the head of the column on the drum is the same as the difference of degrees; then, reading on the central scale the degree of temperature on the wet bulb thermometer opposite this figure on the revolving drum, is found the degree of humidity in the atmosphere. This instrument, as received from the maker, was tested at a temperature of 88°, when four observations gave a mean excess of humidity of 10%. The original heavy connecting strands from the well to the bulb were then removed, as they locally increased the humidity of the air near the bulbs, and a connection composed of eight strands of soft darning cotton was substituted, with the result that the next four exposures showed only 4% of error. These thermometers, too, were not graded on the stems, nor had any of them been verified. I believe these discrepancies would not occur if the instruments were mounted with correctly made and verified thermometers. Either pattern, on account of there being no necessity for the use of tables and calculations for reduction, would be very serviceable for mill use, if constructed correctly as regards grading and after having been tested.

I make this difference still more distinct by appending a table of test experiments made by a

competent observer under the Kew Observatory rules between the standard London instruments—having been duly tested—and the thermometers of Huddleston's instrument. The difference is remarkable and, as can be seen, is greatest at the highest temperatures.

COMPARATIVE READINGS AND REDUCTIONS OF CASELLA'S HYGROMETER AND HUDDLESTON'S HYGROPHANT.

AUG. 27 94.	CASELLA'S.			HUDDLESTON'S		
Time.	Dry Bulb °	Wet Bulb °	Humidity °/o	Dry °	Wet °	Humidity °/o
			Exposed	in the Shade.		
11-45	60·7	57·2	79·7	60·7	57·9	83·9
12-45	60·7	57·4	80·9	60·7	57·8	83·3
1-45	60·8	57·2	79·2	60·8	57·8	82·4
2-45	61·0	57·5	79·5	60·9	57·9	82·9
			Exposed in	Spinning	Room.	
3-30	87·7	75·7	52·0	82·2	74·3	64·6
3-45	88·3	75·8	50·5	84·3	75·0	59·1
4-0	88·7	76·1	48·2	85·8	75·9	58·3
			Exposed in	a Cellar.		
5-0	58·9	57·3	89·7	61·2	58·4	83·4
5-45	58·7	57·0	88·8	59·3	57·5	89·2
6-45	58·5	56·9	89·4	58·9	57·2	88·8
7-45	58·4	56·8	89·4	58·7	57·0	88·8

In every case the instrument, to be reliable, must comply with certain standard requisites: the distance apart of the thermometers, the position of the well of water, size of the aperture of the neck of the well bottle, and the thickness of the strands conveying the moisture from the well to the wet bulb. All should be in consonance with the experience of those who have made a careful study of this subject. In all cases of my observation, two standard instruments were employed, furnished with the same water, attached on opposite sides of the same pillar or column of the mill; and the reductions were calculated from Professor Glaisher's Hygrometrical Tables, 7th Edition, the tenths of a degree in either bulb being worked out by interpolation with the nearest factors.*

* Since the above was written Messrs. Casartelli of Manchester have produced a Mill Hygrometer which conforms to the requirements, theoretical and practical, herein enunciated, and which is free from the ordinary defects of this class of instrument. It has been tested against the standard Kew instrument and found unimpeachable in accuracy.

HYGROMETRICAL OBSERVATIONS IN COTTON SPINNING.

REDUCED AS PER PROF. GLAISHER'S "HYGROMETRICAL TABLES," 7TH EDITION.

Mill.	Room.	Counts.	Hygrometer.		Dew. Point.	Elastic force of Aqueous Vap.	Weight of Vapour per Cubic Foot.	Maximum Weight of Legal Limit.	Weight of Vapour if Saturated.	Humidity of Room.	Humidity of the Outside Air.
			Dry Bulb.	Wet Bulb.							
"A"											
[A]											
	Cards		79·4°	64·6°	54·5°	0·425"	4·54 grs.	8·17 grs.	10·76 grs.	42 °/o	94 °/o
	No. 2 Sping.	68—88 W	83·1	65·6	54·0	·417	4·48	8·83	12·13	37	,,
	,, 3 do.	68—88 W	86·0	70·6	60·0	·518	5·58	9·50	13·20	42	,,
	,, 4 do.	68—78 W	85·1	69·8	59·8	·517	5·43	9·18	12·90	42	,,
	,. 5 do.	68 W	89·6	72·6	62·0	·553	5·82	10·07	14·64	40	,,
[B]											
	Cards		83·5	67·0	56·0	·449	4·75	8·70	11·70	39	94
	No. 2 Sping.	94—120 W	87·2	71·3	61·1	·539	5·68	9·49	13·69	42	,,
	,, 4 do.	112—128 W	91·5	75·6	65·8	·633	6·37	10·20	14·74	43	,,
	,, 7 do.	115—135 W	85·7	71·8	62·7	·572	6·00	8·99	13·08	48	,,
[C]											
	Cards		77·0	62·0	51·5	·381	4 10	8·00	10·00	41	94
	No. 2 Sping.	90 W	93·3	75·0	63·8	·593	6.19	10·91	16·37	37	,,
	,, 3 do.	90 T	95·2	76·7	65·6	·632	6·56	11·44	17·06	38	,,
	,, 4 do.	80—90 T	91·1	75·3	65·5	·626	6 58	10·32	15·34	42·5	,,
	,, 5 do.	90 T	91·9	76·2	66·5	·651	6·83	10·08	15·70	43	,,
	Combers		77·0	61·9	51·3	·379	4·08	8·00	10·00	41	,,
[D]											
	Cards		82·9	66·8	55·8	·450	4 77	8·41	11·25	40	94
	Frames		87·7	68·5	56·2	·453	4·78	9·34	13·88	35	,,
	No. 3 Spirg.	90 W	93·0	74·8	63·7	·590	6·14	11 00	16·20	37·5	,,
	,, 4 do.	90—89 T	94 6	77·0	66·4	·648	6·74	10·92	17·00	42	,,
	,, 5 do.	70—100 T	93·5	77·9	68·5	·695	7·30	10·85	16·45	44	,,
	,, 6 do.	100—120 T	88·7	74·8	66 0	·638	6·75	9·76	13·59	47	,,
"B"											
[A]											
	Cards		71·3	58·6	48·9	·348	3·79	7·04	8·36	45	80
	No. 1 Sping.	120—160 W	93·5	73·9	62·0	·556	5·81	10·85	16·45	35	,,
	,, 2 do.	110—140 W	93·7	73·6	61·4	·545	5·67	10·79	15·71	34	,,
	,, 3 do.	110—140 W	96·1	74·3	61·4	·545	5·68	11·76	17·75	31·5	,,
	,, 4 do.	85—120 W	85·1	69·8	59·8	·517	5.23	9·18	12·64	42	,,
[B]											
	Cards		73·7	62·2	53·8	·416	4·49	7·28	8·47	49·5	80
	No. 1 Sping.	110 W	86·8	68·9	57·4	·472	4·99	9·26	13·52	36	,,
	;, 2 do.	110—120 W	90·6	73·5	62·9	·511	5·99	10·03	15·10	40	,,
	,, 3 do.	100—120 W	89·1	72·5	62·1	·555	5·84	10·22	14·44	40	,,
	,, 4 do.	120 W	87·0	70·0	59·1	·502	5·30	9·55	13·60	39	,,
[C]											
	Cards		87·0	69·3	57·9	·482	5·90	9·55	13·60	37·5	80
	Frames		88·3	69·0	56·8	·461	4 93	9·81	14·18	34·5	,,
	Combers		70·5	57·5	47·6	·330	3·60	7·08	7·75	46	,,
	No. 1 Sping.	50 T—78 W	98·6	77·4	65·1	·622	6·40	11·76	17·22	35	,,
	,, 2 do.	100 W	96·7	77·5	66·3	·643	6·63	11.59	17·95	37	,,
	,, 3 do.	60—80 W	96·3	77·5	66·1	·639	6·57	11·71	18 13	37·5	,,
	,, 4 do.	60—80 W	90·6	72·9	61·9	·552	5·81	10·12	15·10	38·5	,,

HYGROMETRICAL OBSERVATIONS,—*Continued.*

Mill.	Room.	Counts.	Hygrometer. Dry Bulb.	Hygrometer. Wet Bulb.	Dew Point	Elastic force of Aqueous Vap.	Weight of Vapour per Cubic Foot.	Maximum Weight of Legal Limit.	Weight of Vapour if Saturated.	Humidity of Room.	Humidity of the Outside Air.
"C"											
[A]	Cards		79·2°	63·7°	53·3°	0·404"	4·32grs	8·21grs	10·68grs	41 %	87%
	No. 1 Sping.	40—60 T	92·5	72·2	59·8	·513	5·33	10·55	15·95	33·5	,,
	,, 2 do.	50—60 T	93·6	72·9	60·3	·525	5·41	10·82	15·78	32·5	,,
	,, 3 do.	60—70 T	91·6	72·6	60·9	·533	5·66	10·17	15·58	36	,,
[B]	Cards		80·6	64·1	52·9	·401	4·27	8·40	11·18	38	87
	No. 1 Sping.	60 T	90·8	70·8	58·4	·487	5·16	10·06	15·20	34	,,
	,, 2 do.	60 T	91·3	72·1	60·2	·520	5·50	10·26	15·42	35·5	,,
	,, 3 do.	60 T	80·7	67·1	57·6	·479	5·16	8·41	11·21	46	,,
[C]	Cards		70·70	56·7	46·2	·312	3·37	6·98	8·21	41	87
	No. 1 Sping.	40—60 T	85·0	61·8	46·9	·322	3·40	9·20	13·20	27	,,
	,, 2 do.	40—60 T	62·9	50·7	40·3	·229	2·75	5·22	5·88	43·5	,,
	Winding		58·7	50·9	49·4	·288	3·21	4·58	5·54	58	,,
"D"											
[A]	Cards		76·4	62·0	51·9	·387	4·16	7.62	9·82	42	87
	No. 1 Sping.	62 T	96·4	75·1	62·6	·567	5·91	11·61	17·92	33	,,
	,, 2 do.	62 T	102·4	79·6	64·6	·609	6·12	13·40	19·62	31	,,
	,, 3 do.	52 W	99·6	78·6	66·6	·634	6·72	12·16	19·60	34	,,
	,, 4 do.	52 W	89·3	73·8	64·1	·595	6·29	10·16	14·52	42	,,
[B]	Cards		83·70	66·7	55·4	·438	4·67	8·71	12·28	38	87
	No. 1 Sping.	60 T & W	92·0	71·8	59·4	·505	5·24	10·70	15·70	33·5	,,
	,, 2 do.	70 T & W	99·0	75·0	61·3	·550	5·60	12·30	19·30	30	,,
	,, 3 do.	62 T & W	95·6	72·7	59·1	·502	5·15	11·32	17·50	30	,,
"E"											
[A]	Cards		85·7	67·8	56·1	·452	4·77	9·06	13·08	36	94
	Frames		83·9	66·9	55·6	·443	4·69	8·88	12·38	38	,,
	Combers		77·5	63·6	53·9	·425	4·42	8·10	10·14	44·8	,,
	No. 1 Sping.	32 T	94·8	74·4	62·1	·560	5·78	11·34	17·10	34·2	,,
	,, 2 do.	60 T	95·7	75·6	64·0	·597	6·11	11·68	17·49	35·2	,,
	,, 3 do.	64 T	94·1	73·4	60·9	·535	5·51	11·14	16·75	33·7	,,
	,, 4 do.	50 T	87·6	69·6	58·1	·485	5·13	9·67	13·85	37·0	,,
"F"											
[A]	Cards		75·2	63·3	54·8	·429	4·79	7·69	9·46	49	95
	Frames		79·8	65·3	55·4	·439	5·41	8·11	10·12	42·5	,,
	Combers		81·8	67·1	57·2	·469	6·30	8·76	11·62	42·7	,,
	No. 2 Sping.	90	85·8	71·8	62·7	·570	7·14	9·36	13·12	46·8	,,
	,, 3 do.	70	85·6	72·3	63·6	·589	6·84	9·32	13·04	48·1	,,
	,, 4 do.	65	86·8	73·4	64·8	·613	7·12	9·74	13·62	48·6	,,
	,, 5 do.	50	83·6	70·8	62·3	·564	6·32	9·03	12·24	49·2	,,

HYGROMETER READINGS TAKEN IN JUNE 1894, TO COMPARE WITH THE FOREGOING TABLES TAKEN IN WINTER, 1892-3.

Mill.	Rooms.	Counts.	Hygrometer.		Dew Point.	Elastic Force.	Weight of Vapour.	Weight of Vapour if Satu ated.	Humidity of Room.	Humidity of same room in Winter.
			Dry Bulb.	Wet Bulb.						
"B"										
	Mixing	—	64·7°	55·5°	47·2°	·320"	3·58gr.	6·80grs	51 %	—
	No. 4 Sping.	120s	86·5	72·2	62·9	·573	6·06	13·13	46·4	43%
	„ 3 do.	110—140	86·2	71·9	62·6	·570	6·04	13·5	45	42
"C"										
	Mixing	—	72·1	61 0	52·6	·398	4·39	8 48	51	—
	(Cards) end	—	77 0	64 0	54 9	·431	4·6	8·9	47	36
	„ centre	—	79·0	65·1	55 6	·444	4·76	10·63	41	—
	No. 2 Sping	60s	89 2	72 0	61·2	·539	5·68	14·36	38·6	35·2
	„ 3 do.	60s	91 8	72·3	60·3	·522	5·54	15 28	35	33·7
"D"										
	Mixing	—	66·2	56·0	47·8	·231	3·68	6·96	51·4	—
	No. 2 Sping.	60s	93·4	72·5	59 8	·514	5·31	16·33	32·2	31
	„ 3 do.	60s	97·8	76·8	64 6	·608	6·26	18·36	33 8	30

MILL IN RUSSIA PROVIDED WITH SPRAY HUMIDIFIERS.

Card Room	—	82·0°	73 0°	67·0°	0 662"	7·10gr	11·70gr	60%
Combers	—	87·0	75·0	67·3	·669	7·0	13·60	52
Mules	—	88·0	74·0	65·1	·619	6·50	14·0	46

The rooms of the mills in which the readings were taken, the numbers spun in each mill, the percentage of saturation of the outside atmosphere, the readings of the dry and wet bulb, temperature of the dew point, elastic force of aqueous vapour, weight of vapour per cubic foot of air, weight of vapour if air was saturated, vapour required for saturation of each foot of air, percentage of humidity. (saturation point=100), will all be found in the table.

It will be seen from the foregoing tables that there is a considerable diversity in practice in mills spinning much the same numbers and presumably much under similar conditions. It will be further noticed there is not the difference popularly supposed to exist between the mills spinning extra fine and those spinning medium numbers. As a matter of fact, there are no large modern mills spinning very fine. This trade, such as it is, lies pretty well in the hands of old established firms in possession of ancient buildings which, although ancient, are suitable for this class of work. It is, of course, within the knowledge of all interested in the cotton trade, that numbers, in the last twenty-five years, have become gradually coarser, on the average, for better classes of yarn; the explanation of this being that improvements in the exactness of process has enabled, in many cases, single yarn to replace doubled yarn of twice the fineness; if not as perfect in result at least as perfect as the competition in the article manufactured requires. Thus the standard 60's twist of to-day replaces the 120's doubled of 25 years ago.

I will now give an interesting comparison of a typical mule room, the temperature at which the mills were working, weight of aqueous vapour which the limit of the Act of Parliament permits in weaving mills, weight of water it would represent if condensed, the relative humidity being given in each instance, compared with the same quantities existing at the time the observations were being made in four mills.

HUMIDITY OF SPINNING MILLS—A MULE ROOM 230ft. × 120ft. × 13ft. = 358800 feet.

MILLS.	Grains of Aqueous Vapour.	Gallons of Water if Condensed.	Relative Humidity.
"A" Temperature of room 86°F.			
Max. Weight of vapour permitted by Act of Parliament* ..	3408600	48·7	72 0°/o
Weight actually in the room†	2332200	33·3	48·6
Below Max. limit‡	1076400	15·4	23·4
"B" Temperature of room 94°F.			
Max. Vapour permitted	3982680	56·9	66°/o
Weight actually in the room	1976988	28·2	33·7
Below Max. limit	2005692	28·7	32·3
"C" Temperature of room 100°F.			
Max. Vapour permitted	4556760	65·1	64°/o
Weight actually in the room	2009280	28·7	30
Below Max. limit	2547480	36·4	34
"D" Temperature of room 96°F.			
Max. Vapour permitted	4233840	60·5	66°/o
Weight actually in the room..	2378844	34·0	37·5
Below Max. limit..	1854996	26·5	28·5

* *MAXIMUM* weight of Aqueous Vapour allowed under the provisions of the "Cotton Cloth Factories Act, 1889."
† Weight of Vapour in the Spinning Room on the day the observations were taken.
‡ The difference between the weight legally sanctioned and what the respective mills were working.

"A." "B." "C."

I give also a reproduction of photo-micrograph showing yarn spun in mills "A," "B" and "C"; all being No. 60's twist. It will be seen that yarn "A" is a more solid and regular thread than the others. I may say that its test in strength bears out this.

I have to call special attention to this illustration because although the zincograph does not give quite the whole of the detail of the photograph, it shows sufficiently clearly the enormous difference existing. This difference is quite as noticeable and striking in the whole of the photographs that have been taken, that selected being considered a fair average of the others.

The following table will show a microscopical test, from which may be clearly deduced the superior regularity of yarn in mill "A", the different mills being named by letters, "A," "B," "C."

MICRO-MEASUREMENTS OF THE DIAMETER OF THREE SAMPLES OF YARN.

MICROMETER LINES = $\frac{1}{3000}$ INCH.

"A"—60's T. No. of lines.		"B"—60's T. No. of lines.		"C"—60's T. No of lines.	
9	9	11	13	14	20
8	9	11	11	12	16
9	9	10	11	13	13
8	8	12	10	18	12
8	8	11	8	14	14
	8	10	9	13	14
7	9	12	8	19	17
11	9	12	13	13	12
9	10	13	14	14	22
9	8	12	11	19	20
10	7	10	12	13	19
10	7	9	10	17	21
Mean = $8\frac{15}{24}$ Range of 4 lines.		Mean = $10\frac{23}{24}$ Range of 5 lines.		Mean = 16 Range of 10 lines.	

From the table of comparison of the four typical mills on page 29 it will be seen that the mill "A" approaches, in percentage of humidity, more nearly the Act of Parliament than any of the others; and this, indeed, is the only difference that will explain the smoothness and roundness and superior regularity. Of course, the instances given are only typical, and carefully selected as fairly average cases. I believe I can guarantee their exactness.

Having now endeavoured to show the importance of this question of humidity, its relation to electricity, and the want of similarity in practice, I will proceed to describe the different methods adopted for the purpose of regularising the moisture of the air, their success or otherwise, and, finally, give an opinion as to the temperature and humidity most desirable, and the simplest and easiest method of accomplishing this.

UTILIZATION OF NATURAL EVAPORATION.

The simplest method of increasing the humidity of the air in a room is by sprinkling water upon the floor and trusting to the natural evaporation which, of course, is more speedy with high temperatures than with low. This is known, in Lancashire, as "degging," and is practised to an extent hardly thought of, especially in manufactories unprovided with more perfect systems—more perfect only as referring to its automatic supply, because evaporation from a regularly sprinkled floor secures a diffusion of humidity, the regularity of which cannot be surpassed. But the system is troublesome, requires manual labour, is dependent upon the exactness of an individual, and the continual dampness of the floor is often supposed to cause rheumatic afflictions to the

workpeople. Again, in some weaving sheds, channels have been made in the floor which have been partially filled up with bricks, making a perfectly level surface, with interstices. These channels drain down, generally, to one end or side of the room and the water is allowed to flow through the channels, the idea being that the bricks will absorb the water and render it, by evaporation, to the room. Further, these channels have, as a rule, been taken under the looms. The writer much doubts, however, if they are kept in actual operation in those places where they have been constructed, the reason for this being that the tacklers object to tackle the loom and having to lie on their backs upon the damp bricks. Further, the interstices between the bricks or tiles soon get made up with the dirt and waste from the floor; and as the thorough cleaning periodically would be a considerable labour it is simply left undone. If the surfaces of exposure were sufficient, the required amount of humidity could well be gained by this system, which would be satisfactory—apart, of course, from its practical objections.

Another method of utilising natural evaporation, and one free from the objections named in the above remarks is that of shallow water troughs making the circuit of the room or crossing at different distances according to requirements, the surface exposure of the troughs bearing a relation to the cubical content of the room to be humidified. These troughs are sometimes placed over the heating steam pipes, at other times underneath, and, occasionally, suspended from the ceiling joists without reference to the position of heating pipes. In every case the water is allowed to enter at one end of the room and to flow, by gravitation, slowly along the troughs to the other extremity, where the water is collected for re-use, or for some other purpose. But this, after all, is

unimportant, the main object being to supply the water at about the temperature of the room, and by sufficient motion to allow the globules to be successively subjected to the absorbing power of the air.

To deal with the advantages or disadvantages of these three arrangements, I may say that where the troughs are placed over the steam pipes they can be carried by the pipes on brackets, and, as the steam pipes themselves are generally regulated with a view of allowing the water formed by condensation to gravitate to one extremity, the troughs will also follow this inclination. The pipes being underneath, the heat radiating has, of course, a tendency to increase the natural evaporation. When the troughs are suspended from the heating pipes the radiation also acts upon the evaporation, and the troughs themselves form a shield to prevent the direct rays of heat from affecting the workpeople.* When the workperson has to stand directly under the steam pipes, headache and nausea are often produced. This would seem to be, then, in favour of this system. Moreover, any leakage from the joints of the steam pipe would fall into the trough instead of on to the floor. Where the troughs are placed near the ceiling, they have the advantage of not interfering with the passage of light to such a degree as when in other positions, and, also, of being in that part of the room where the heat is greatest and, consequently, the evaporation most active.

There are partizans of each of these systems, but, as they can all three produce practically the same result, I will leave the matter as one of taste, only remarking, that in considering this, the height of the room must be taken into account.

* As between the positions of the trough above the steam pipe and underneath, the relative evaporation is:—above, 0·39in.; below, 0·46in., showing an advantage in evaporation in favour of the troughs being below, in addition to the further advantages enumerated.

The foregoing represents, briefly, all that has been done in utilising the principle of natural evaporation.

ARTIFICIAL METHODS OF PRODUCING MOISTURE.

We have now to consider the artificial methods of producing moisture. In all systems the water, contained in the air in a state of suspension, is either a chemical or mechanical mixture. What I would say is that natural evaporation means general diffusion and intimate and atomic assimilation. Air and water so assimilated have no tendency to separate until the conditions of temperature or pressure have necessitated it.

Now in all mechanical appliances for distributing fine particles of water in a proportionate quantity of atmosphere, there is a limit to the power of atomization or pulverization; and, no matter what pressure be used, the sub-division into particles is infinitely inferior in number to the result of natural and free evaporation. Therefore, any system of this kind, whatever its name may be, can only be relatively advantageous as compared with natural systems. If we take another illustration—in a case where spray and vapour are produced by physical force, such as vapour rising from the ground during an excessively heavy rain storm, or the spray formed by a gigantic waterfall—it will be found that the effect of the humid air is confined to a short radius round the centre of action; but where the rising sun, heating damp ground causes a mist this does not fall in the shape of rain or dew, but is gradually absorbed owing to the increasing elastic force of aqueous vapour. I hope this will make plainer my remarks with regard to the difference between chemical and mechanical moisture and afford further proof of the advantage of the natural method.

Thus it is found by absolute observations that the conditions of moisture in a room naturally humidified is very much more equal than in any mechanical system. This is explained by the facility with which natural vapour can be assimilated by the neighbouring air, as opposed to the mechanically powdered water; and may be illustrated by an example in chemistry where in a perfect chemical solution it is possible to continue dilution until the absorbed substance is one part to a million. In a simply mechanical mixture the limit of dilution is quickly reached. Thus all systems, which have, for principle, the pulverization of water, have the initial defect I have alluded to; and they can at best be but a rough and ready way of attempting to solve what is, after all, a simple problem.

EQUABLE HYGROMETRIC CONDITIONS.

In this regard I have some observations which show how impossible it is to arrive at equable hygrometric conditions with mechanical methods. The apparatus employed was, perhaps, one of the best of the mechanical systems; the room was 150 feet by 50 feet, the height about 13 feet, and the apparatus was placed about 15 inches from the ceiling. The action of the apparatus was also assisted, as regards diffusion, by ventilating tubes, which introduced fresh air at many points in the room.

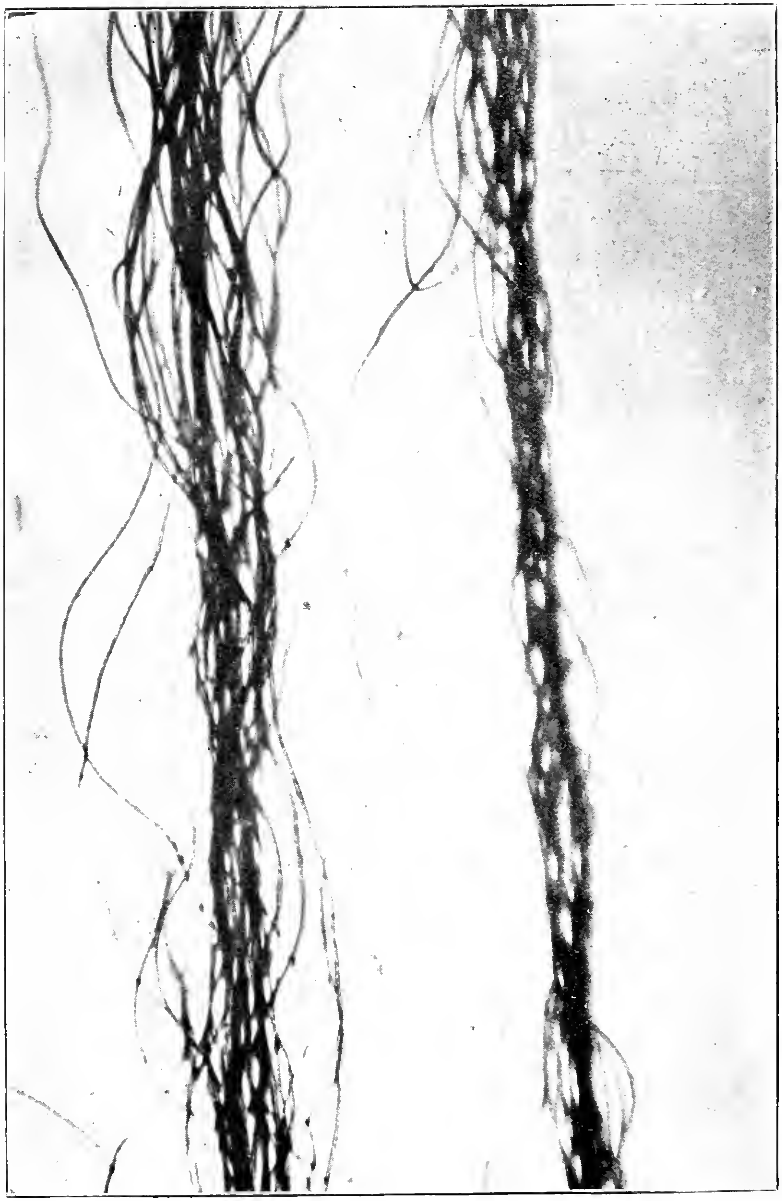
No. 1 room showed the humidity of the air to be, at 10 inches from the apparatus, 95 per cent; at 3 feet away, the mean of a number of observations showed 75 per cent. of humidity, at 12 feet away from one instrument it was nearly 60 per cent. In these cases, the temperature close to the apparatus was 60 deg.; 3 feet off, 63 deg.; and 12 feet distant 71 deg.—showing, in addition to the difference in humidity, a considerable range of temperature

in the same room. There was, also, a well defined, but inexplicable range of percentage of humidity 3 feet away from the instrument, the range being no less than 12 per cent from 11 o'clock to 1-40. This might be traced, no doubt, to some accidental current of air. But more extraordinary was the fact, absolutely proved, that in 10 minutes the temperature varied from 63·2 deg. to 65 deg., and the percentage from 77 to 68. At the farther end of the room, 5 feet from a blank wall, with no door or opening, the temperature changed, in 20 minutes, from 68·4 deg. to 71 deg. and the percentage of humidity from 62½ to 56. In a similar room, but without humidifiers, the observations showed a range of temperature of 4·2 deg. and 9 per cent. of humidity. The variation would not have been so great as this but for the fact that there were open windows at one end, which decreased the percentage; but the readings of the observations were generally more equable. The temperature of the atmosphere outside was 47·3 deg. and the percentage of humidity 67.

As a further proof of the inefficiency of this system of humidifying, I point to the fact that it is not practicable to place this apparatus near moving bodies, such as driving straps or shafts. In any case, where there is an induced current of air, precipitation takes place. To such an extent is this so, that the apparatus has had to be moved from the centre of the room to the sides, to avoid the action of the shaft and straps upon the air.

OBSERVATIONS WITH AND WITHOUT HUMIDIFIERS.

I think it will prove useful to here append reproductions of photo-micrograph typical of woollen yarn spun, with and without humidifiers on the day the observations were taken.



ORDINARY X 40. | HUMIDIFIED.

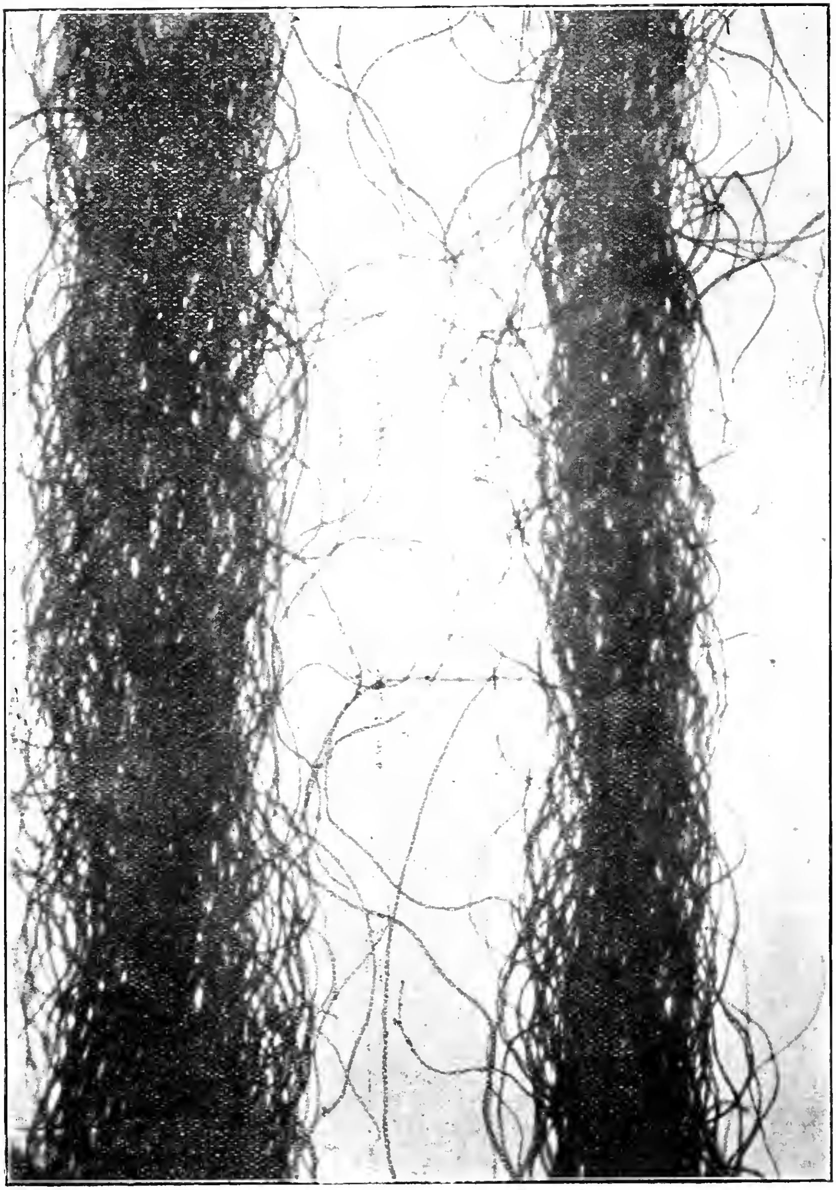
It will be noticed that as in the photographs of the cotton yarns, the same result is apparent. That is to say, the yarn spun under moisture is more solid, consistent, and regular. The examples given were spun from the same preparation, out of the same wool and the same numbers; although this is difficult to believe from the photograph—multiplied 40 diameters.*

To make even still clearer to the eye the extraordinary difference in the compactness of the fibre under operation in the various conditions of humidity or dryness, I give another photographic illustration (see page 40) of woollen sliver multiplied 20 diameters; No. 1 worked in the ordinary air of the mill, and No. 2 in a room provided with humidifiers; the numbers, fibre, speed of machines, and every condition, except the humidity, being precisely alike.

In a visit to the United States, where, as I have said previously, this question is one of great importance and where many inventions have been tried, I had an opportunity of inspecting various systems. I state unhesitatingly, there was more or less precipitation in every case of mechanical humidification. This will be easily comprehended when I remark that, in a state of the slightest motion, air will not carry a greater weight than 80 per cent. And the quicker the motion of the air, the greater the precipitation.

I scarcely know whether it would be time well spent to discuss the bearings of the question of live steam admitted in the working rooms. There may be manufactories where such a course is necessary, but I do not know of any; and most certainly spinning and weaving are not in the category. As has been pointed

* Whilst correcting the final proofs I have been again struck with the remarkable difference shown in the photograph as between the two yarns. I can only attribute it to the fact that the magnified photograph shows, and perhaps may exaggerate, the peculiar difference really existing. One thing I will guarantee is that these yarns are fair samples of the bulk and that no attempt has been made to enlarge the difference for the sake of effect.



ORDINARY X 20. | HUMIDIFIED.

out previously in this paper, live steam will increase rather than diminish the electrical difficulty, particularly with wool stock much more than with cotton. It is exceedingly unpleasant to the persons working in the room; and, I think it is generally admitted, very injurious to their health. It is therefore undesirable, from every point of view; and as proper conditions of the air can be so easily arranged in other ways there would seem to be little excuse for a continuance of this practice. I am glad to say that, personally, I do not know of any mill in this country where such a practice obtains, although I have seen it often enough abroad.

MECHANICAL versus NATURAL HUMIDIFIERS.

Taking into consideration the cost of the plant, the power, the cost of supervision, the cost of replacement and repairs necessitated where artificial humidifiers are employed, and, above all, the inefficiency and inequality of the result as compared with the system of evaporation, I feel justified in declaring that, in my opinion, the cheapest, most efficient, most regular, and simplest method of maintaining a constant degree of humidity in an enclosed body of air is the application of some simple system of natural evaporation.

That it may be clearly understood what is to be done to arrive at the best result for practical working in cotton mills, I give a carefully prepared table showing the readings of the dry bulb and the wet bulb, together with the degree of humidity best calculated for the thoroughly good working of the material operated upon. It will be found that the results are much under those allowed by the Cotton Cloth Factories Act of 1889. Thus, take 90 degrees. The utmost humidity necessary would be 49 per cent. as against 69 allowed by the Act;

at 80 deg. it would be 52 as against 77·5; at 70 deg. 53 per cent. as compared with 88; and at 60 deg. it would be 54 per cent. as against 88 per cent. allowed by the Act. Thus leaving out the question of weaving sheds, which require more humidity than spinning mills, cotton spinners will see they have absolutely nothing to fear if working under this Act of Parliament.

Humidity, and weight of vapour per cubic foot, for Spinning Rooms, at temperatures varying from 100° to 40° F, and the temperature at which the "Wet Bulb" Thermometer should read to attain it:—

Dry Bulb.	Relative Humidity.	Weight of Vapour Grains.	Wet Bulb.	Dry Bulb.	Relative Humidity.	Weight of Vapour Grains.	Wet Bulb.
100°	46%	9·2 grs.	85·5°	70°	53%	4·3 grs.	60·0°
99	46	9·0	84·0	69	53	4·1	59·0
98	47	8·8	83·6	68	53	4·1	58·3
97	47	8·6	82·3	67	53	3·9	57·3
96	47	8·3	81·3	66	53	3·8	56·3
95	48	8·3	81·0	65	53	3·7	55·5
94	48	8·0	80·0	64	53	3·5	54·5
93	48	7·8	79·0	63	54	3·4	53·7
92	49	7·7	78·6	62	54	3·4	53·0
91	49	7·6	77·7	61	54	3·2	52·0
90	49	7·3	76·7	60	54	3·1	51·0
89	50	7·2	76·3	59	54	3·1	50·3
88	50	7·0	75·3	58	54	3·0	49·3
87	50	6·9	74·6	57	54	2·8	48·3
86	51	6·6	73·5	56	54	2·7	47·5
85	51	6·5	72·6	55	55	2·6	46·7
84	51	6·3	72·0	54	55	2·6	46·0
83	51	6·1	71·0	53	55	2·5	45·0
82	51	5·9	70·0	52	55	2·5	44·3
81	51	5·8	69·3	51	56	2·4	43·5
80	52	5·7	68·6	50	56	2·3	42·5
79	52	5·5	67·7	49	56	2·2	41·7
78	52	5·4	66·7	48	57	2·2	41·0
77	52	5·2	65·7	47	57	2·1	40·2
76	52	5·1	65·0	46	57	2·0	39·2
75	52	4·9	64·0	45	57	2·0	38·4
74	52	4·7	63·0	44	58	2·0	37·8
73	52	4·6	62·3	43	58	1·9	36·8
72	52	4·5	61·3	42	58	1·8	35·6
71	53	4·4	61·0	41	58	1·7	35·0
				40	58	1·6	34·2

EVAPORATION.

In considering the quantity of water that should be evaporated to produce the wished-for result in the condition of the air it became necessary to experiment as to the rate of evaporation at varying temperatures and to endeavour to find a practicable working mean

that would simply require ordinary attention to maintain the degree looked for. The mule rooms in mills of to-day are built wider and higher than those in the old factories. This necessitates an increased degree of evaporative power. The condition of the exterior atmosphere requires to be still considered, and the more this varies climatically, the more perfect should be the apparatus to enable any requisite adjustment to be made without unnecessary loss of time. Thus in an east wind, any air admitted—which, of course, is a constant occurrence, so long as work is going on—reduces the temperature of the air in the room and absorbs a proportion of the moisture, lowering the general average. In winter, when the air admitted might be fully saturated, introduced at, say, 30 deg., and being saturated with some two grains of vapour per cubic foot if raised to 80 deg. requires about 11 grains per cubic foot to complete saturation; thus calling for a moisture of $5\frac{3}{4}$ grains per cubic foot in the room to raise it to the temperature and humidity requisite. This, and the fact that the material itself is constantly absorbing some of the existent moisture and that there is an inevitable condensation constantly proceeding upon the windows and upon the walls, requires that a quantity of vapour should be replaced continuously. To effectually provide for this is the problem I have had to solve.

It is nearly impossible to quote figures of any exactness to show the loss occasioned by the before-named conditions—climate, position, elevation, exposure, the nature of the building itself, the thickness and fitting of the windows, the facility for the admission of air through the doors, and the number of times that the doors are opened, are all factors varying in different mills, and it would be difficult indeed to lay down any hard and fast rule.

Further, in considering the question in relation to the percentage of humidity desired, it must be borne in mind that the temperature of the room is an important factor in determining the amount of water surface necessary to obtain the deficiency of vapour. Thus the higher the temperature the more difficult it is to maintain the percentage of humidity desired, and, therefore, the greater the evaporative area requisite. For instance, under similar conditions as between 81 degrees and 92·3 degrees the evaporation in the same time was, for the lower temperature 0·14 inches and for the higher 0·295 each 24 hours.

This, of course, was simply an experiment in one portion of the room under ordinary working conditions; but applied to the whole of the room the difference would be more marked on account of the greater surface of walls and windows conducing to condensation.

It may be interesting to show how the experiments with regard to evaporation were conducted. In the first place, they were all taken in an ordinary cotton mill working under supposed normal conditions. A 5in. evaporator was exposed in each position for 48 hours. There were self-registering maximum and minimum thermometers placed in close proximity and the readings noticed each day the instrument was exposed. The reason for the 5in. evaporator being used was to facilitate the accurate measurement of the water evaporated by means of the certified 5 in. rain gauge of the Meteorological Society. The same instruments were used throughout. The proportion of evaporation between the 5in. gauge and one foot square as directly proportioned to their surface was rather over seven to one.

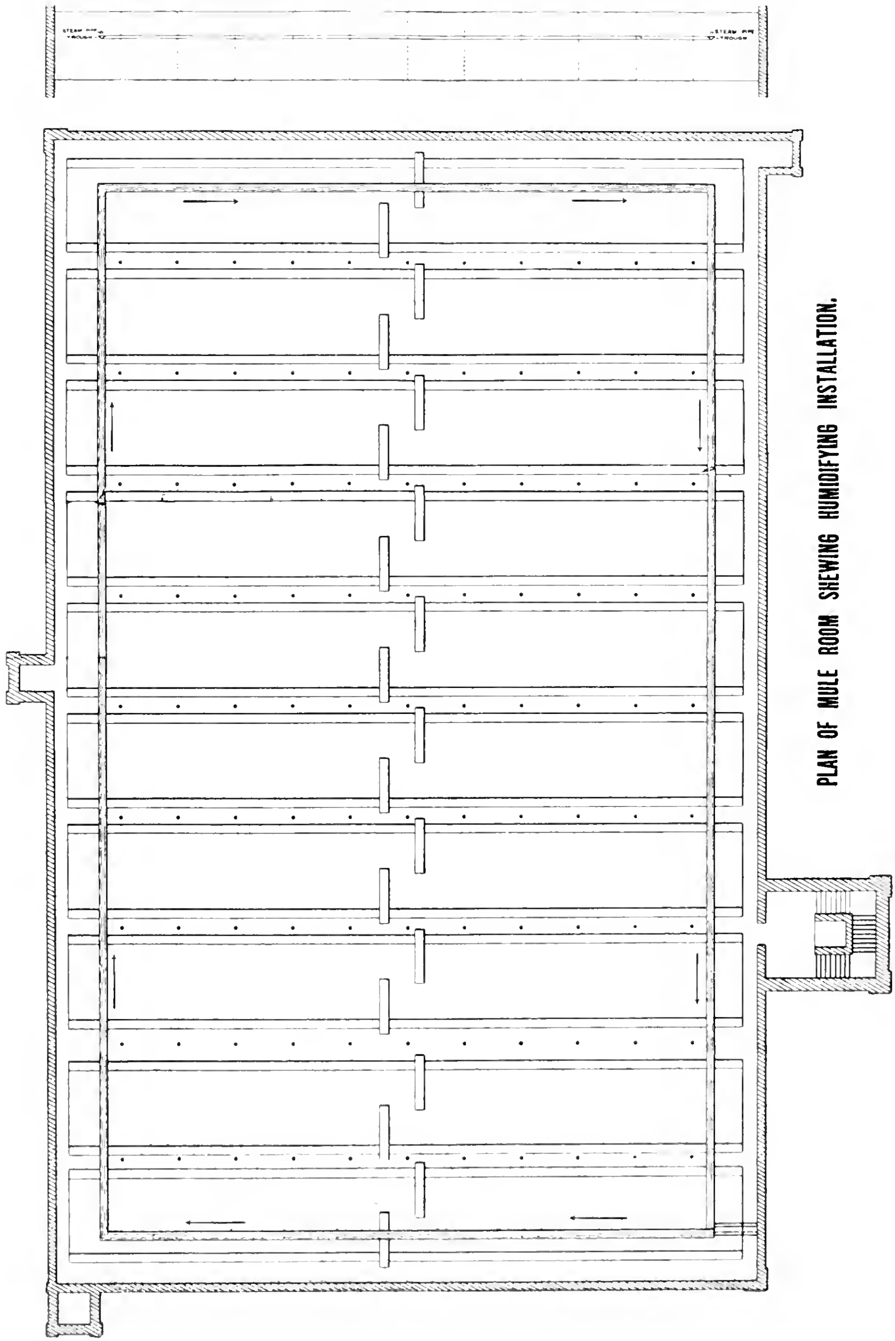
In taking the capacity of the rooms in modern mills and estimating the average temperature customary, it

may be fair to assume that the humidifying plant should not have less capacity than that indicated by the evaporative observations taken under normal working conditions in order to maintain the standard amount of moisture necessary for successful operating of the cotton. This, carried a little further, and granting that a temperature of 90 degrees Fahr. would be the extreme mean temperature at which the room might ever be heated—which, it is hardly necessary to say would allow a considerable margin for contingencies—it would require 3,552,120 grains of aqueous vapour to give a humidification of 50 per cent. in an ordinary mule spinning room of a capacity of 360,000 cubic feet.

Now even in our humid climate in those mills possessed of no artificial means of humidification it is found that there are only some two million grains of vapour present at a temperature of about 90 degrees. The problem is, therefore, to introduce into the air in this room about one and a half million grains more vapour and to maintain that amount.

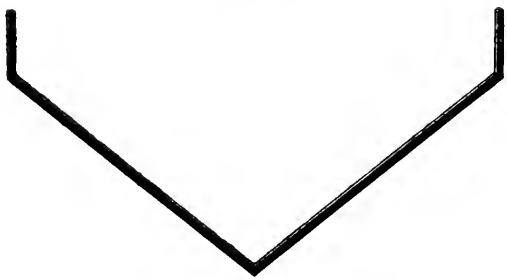
This means, shortly, that each 24 hours 205 lbs. of water should be evaporated. Thus, taking the ordinary mule room and the ordinary amount of evaporation at 90 degrees as 2·163 inches per superficial foot, it would require 758 feet of water surface to supply the difficiency.

In spinning rooms working at a mean temperature of 90 degrees, a trough of water placed 9 feet from the walls round the room, 15 inches wide at the top and reduced by 2 in. steps as shown on page 47, would have an area of water surface of 785 superficial feet. This I believe would be the maximum required for humidifying under the most adverse climatic conditions.

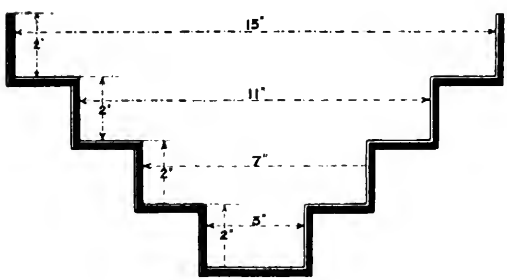


PLAN OF MULE ROOM SHEWING HUMIDIFYING INSTALLATION.

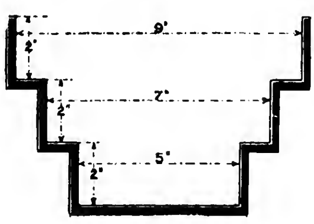
A



B



C



D

The illustration on page 46 shows a mule room with the position of the steam pipes and evaporation troughs. On page 47 various sections of troughs are shown. The forms "A" and "B" are in practical use in some mills; the one marked "C" has not been tried practically but is a suggestion of a method for securing uniform evaporative surfaces throughout the area of the room, the theory being that if there is only one inch of fall from the beginning to the end of the troughs it will be possible to keep the level of the water in the troughs between the limits of one of the steps, thus maintaining a constant surface exposed throughout the room and permitting of a measurable grading of the amount of evaporation.

No other shape of trough except this stepped one can be relied on to give equal results in all its length. The trough is a suggestion of Mr. Midgley, Observator to the Bolton Corporation, and is the outcome of considerable thought and experience. Naturally there must be a supply and exhaust tap for each system of troughs. The method of supply and the dealing with the waste water are subjects that are outside this paper but will no doubt be intelligently dealt with in every case. It is suggested there should be a 2in. supply and a 2in. exhaust tap in order to allow speedy adjustment of the evaporation and that the continuous supply should be by means of a $\frac{3}{8}$in. bye-pass for the normal current. A natural suggestion would be that the water should be raised to the top of the building and allowed to descend from room to room by gravity.

CONCLUSION.

In the card-room, working at a mean temperature of 80 deg. or less, it would require 502,320 grains of vapour more than exists ordinarily. This would be secured

by a superficial area of water surface of 560 feet. A trough 9in. wide, (as shown on page 47, and marked "D") diminished 1in. each step, would fully supply the deficiency.

A modern spinning mill equipped with the above described apparatus and a certified hygrometer should have no excuse for not being in the very best hygrometrical conditions for working the fibre to the very best advantage. Seeing the extraordinary importance of this portion of the industry it is to be hoped that more attention will be paid to the matter than there has been hitherto. The hygrometers should be read two or three times a day and the temperature of the dry and wet bulbs, together with the percentage of humidity, entered in a register for the inspection of the management. If this be done systematically and carefully the average quality of the yarn produced in this country will be improved; less cotton will be lost in invisible waste and fly, and complaint of brittle, hairy or "oozy" and uneven yarn should become a thing of the past.

In the compilation of the whole of the foregoing I have to most heartily acknowledge the very great assistance I have received from Mr. Midgley. The shortness of this paper and the condensed information can hardly give an idea of the enormous amount of labour that has been necessary to arrive at reliable results. For myself I have had only one object, namely, to throw as much light as I could upon what seemed to me to be a *terra incognita*, and to assist, to the best of my ability, the trade of cotton spinning in which I am so deeply interested.

G. S. Heaton, Victoria Printing Works, Bolton.